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# U.S. ENERGY FLOW - 1981

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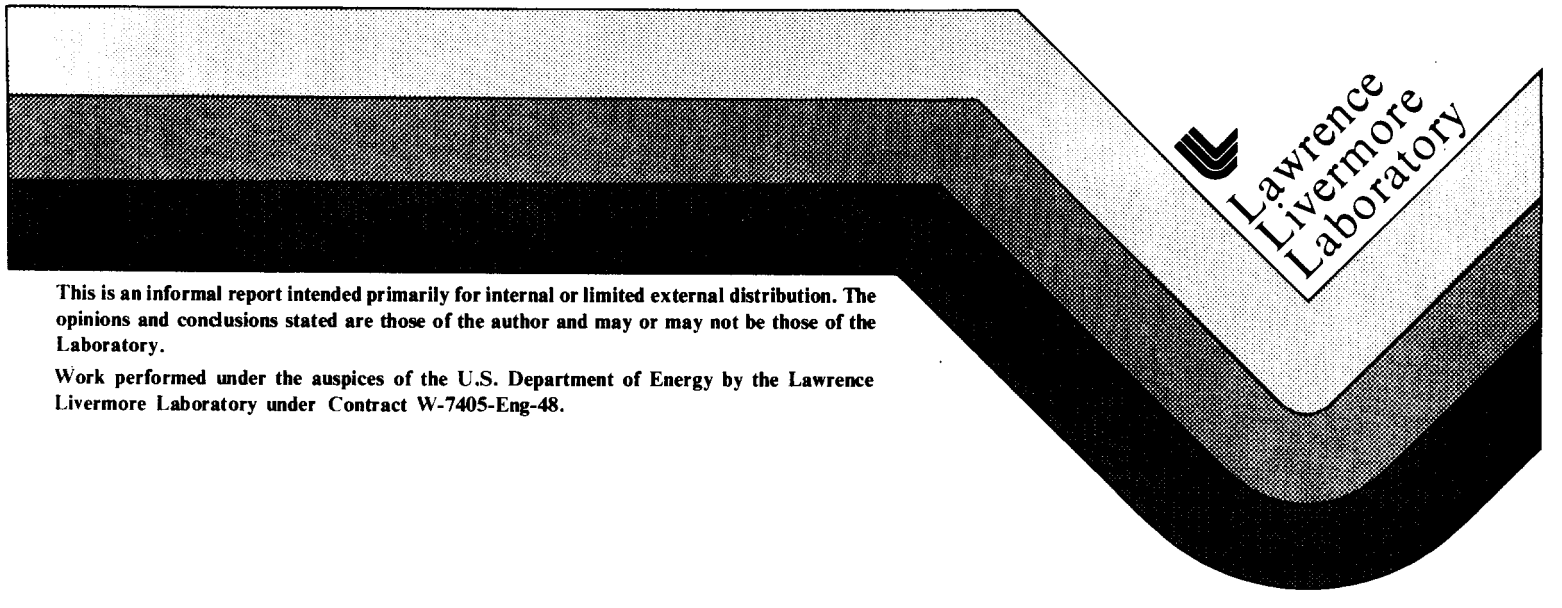
October 1, 1982



## ABSTRACT

Flow diagrams to describe the U.S. energy situation have been prepared since 1972 by the Lawrence Livermore National Laboratory. In 1981 the energy consumption was 73 quads (or 73 x $10^{15}$ Btu) - down from 75 quads in 1980. Oil continues to dominate the picture as it comprises 45% of the total energy used. Net oil use (exclusive of oil purchased for the Strategic Petroleum

# INTRODUCTION

United States Energy Flow Charts tracing primary resource supply and end-use have been prepared by members of the Energy and Resource Planning Group at the Lawrence Livermore National Laboratory since 1972.[1] They are a convenient graphical device to show relative size of energy sources and end-uses since all fuels are compared on a common Btu basis. The amount of detail on a flow chart can vary substantially, and there is some point where complexity begins to interfere with the main objectives of the presentation. The charts shown here have been drawn so as to remain clear and be consistent with assumptions and style used previously.

## ENERGY FLOW CHARTS

Figures 1 and 2 are energy flow charts for calendar years 1981 and 1980[2] respectively.

Data for the flow chart were provided by tables in the Department of Energy Monthly Energy Review, DOE/EIA-0035 (82/05)[3] and the 1981 Annual Report to Congress[4].

The Residential and Commercial Sector consists of housing units, non-manufacturing business establishments, health and educational institutions, and government office buildings. The Industrial Sector is made up of construction, manufacturing, agriculture, and mining establishments. The Transportation Sector combines private and public passenger and freight transportation and government transportation including military operations.

# U.S. ENERGY FLOW – 1981
# (NET PRIMARY RESOURCE CONSUMPTION 73 QUADS)

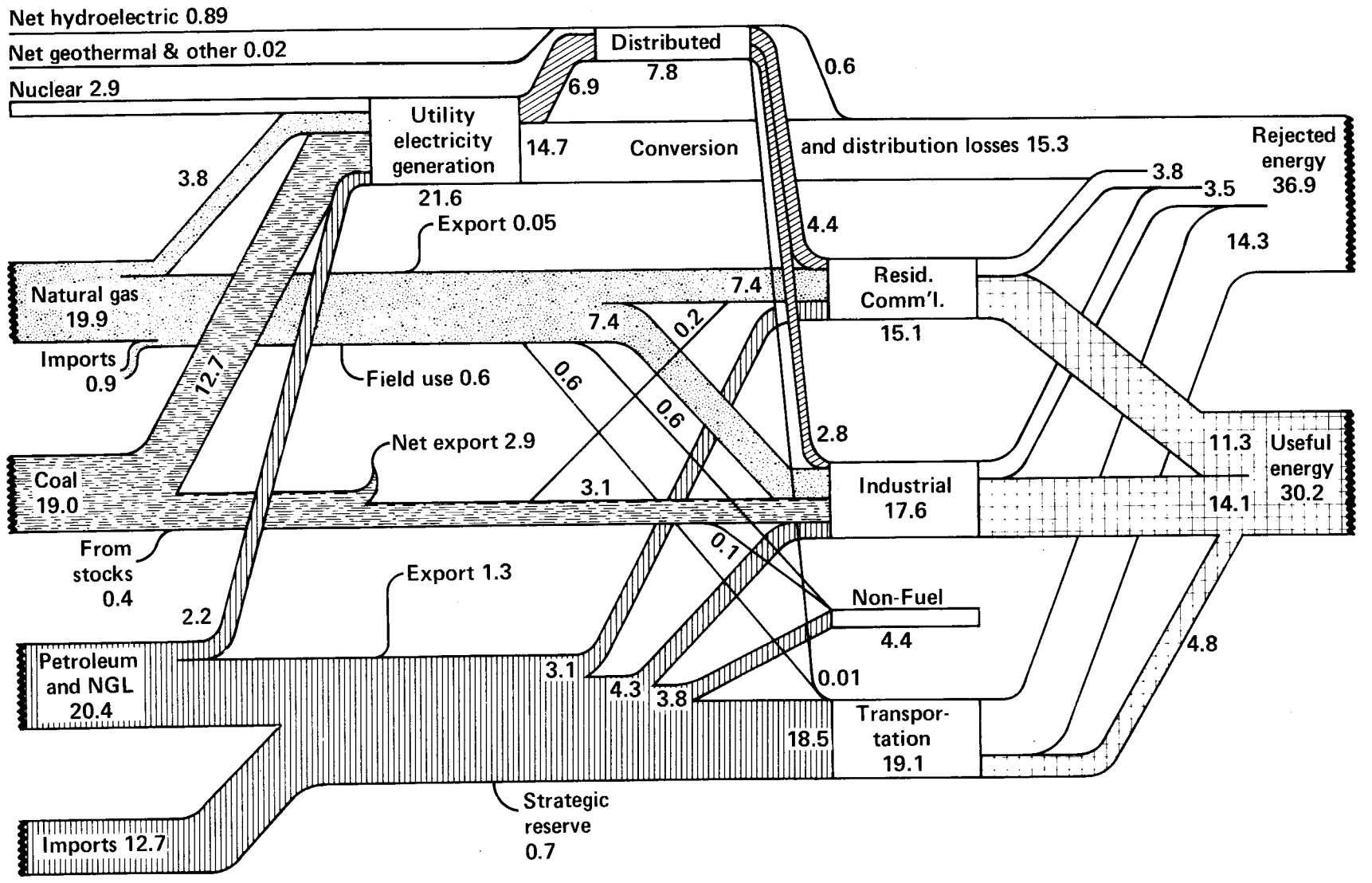



Figure 1

# U.S. ENERGY FLOW – 1980
# (NET PRIMARY RESOURCE CONSUMPTION 75 QUADS)

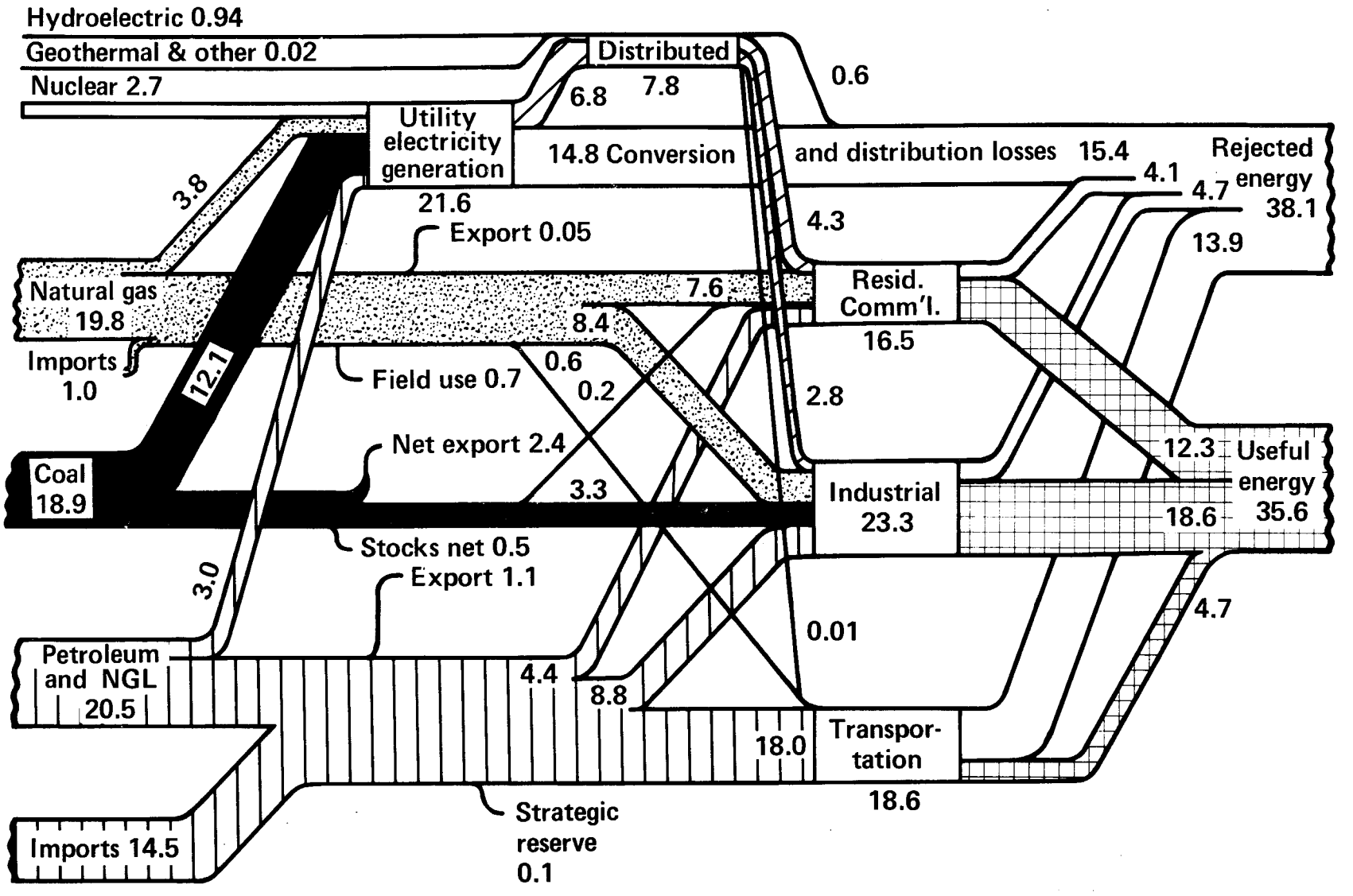



Figure 2

Utility electricity generation includes power sold by both privately and publicly owned establishments.

The appendix lists conversion factors used in converting fuel quantities to Btu.

The division between "useful" and "rejected" energy is arbitrary and depends on assumed efficiencies of conversion processes. In the residential and commercial end-use sectors, a 75 percent efficiency was assumed which is a weighted average between space heating at approximately 60 percent and electrical lighting and other electrical uses at about 90 percent. Eighty percent efficiency was assumed in the industrial end-use sector and 25 percent in transportation. The latter percent corresponds to the approximate efficiency of the internal combustion engine.

## COMPARISON WITH 1980 AND PAST YEARS

Figures 1 and 2 provide graphic comparison of energy use for 1980 and 1981. In 1981 we have added a non-fuel category of end-use.[4] In 1980 it was included in the industrial usage. It consists of fuels that are not burned to produce heat, e.g., asphalt, road oil, petrochemical feedstocks such as ethane, liquid gases, lubricants, petroleum coke, waxes, carbon black and crude tar. Coking coal traditionally is not included. Table 1 lists the consumption of energy resources in the United States for the past five years and gives percentage differences between 1980 and 1981.

For the third year net oil use dropped. An 8.3% decrease followed the 1980 9.2 percent drop. Domestic crude and NGL production changed only

TABLE 1. Comparison of annual energy use in U.S.

| | Quads | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | Change 1981 vs 1980 |
| Natural gas | 19.48 | 19.57 | 19.49 | 20.08 | 20.11 | 19.93 | -0.9% |
| Imports | 0.96 | 1.01 | 0.97 | 1.25 | 0.99 | 0.88 | -11.1% |
| Crude oil and NGL | | | | | | | |
| Domestic crude & NGL | 19.59 | 19.78 | 20.68 | 20.39 | 20.51 | 20.39 | -0.6% |
| Foreign imports (incl. products & SPR) | 15.48 | 18.64 | 17.70 | 17.90 | 14.63 | 12.66 | -13.5% |
| Exports | 0.47 | 0.51 | 0.77 | 1.00 | 1.15 | 1.26 | +9.6% |
| SPR storage reserve* | | 0.04 | 0.34 | 0.14 | 0.10 | 0.71 | +610. % |
| Net use (minus exports & SPR) | 34.60 | 37.87 | 37.27 | 37.15 | 33.89 | 31.08 | -8.3% |
| Coal (incl. exports) | 15.85 | 15.83 | 15.04 | 17.65 | 19.21 | 18.99 | -1.1% |
| Electricity | | | | | | | |
| Hydroelectric (net only) | 0.97 | 0.75 | 0.96 | 0.96 | 0.94 | 0.89 | -5.3% |
| Geothermal & other (net only) | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | -- |
| Nuclear | 2.11 | 2.70 | 2.98 | 2.75 | 2.67 | 2.90 | +7.9% |
| Gas | 3.15 | 3.29 | 3.30 | 3.61 | 3.81 | 3.76 | -1.3% |
| Coal | 9.71 | 10.25 | 10.13 | 11.26 | 12.12 | 12.71 | +4.9% |
| Oil | 3.45 | 4.03 | 3.81 | 3.39 | 2.65 | 2.20 | -17.0% |
| Total fuel | 19.40 | 21.03 | 21.19 | 21.99 | 22.21 | 22.48 | +1.2% |
| Total transmitted energy | 6.96 | 7.25 | 7.53 | 7.67 | 7.80 | 7.83 | +0.4% |
| Residential and commercial | 18.12 | 17.87 | 18.24 | 17.31 | 16.52 | 15.10 | -8.6% |
| Industrial | 22.07 | 22.51 | 22.74 | 24.57 | 23.40 | 22.04 | -5.8% |
| Transportation | 19.04 | 19.71 | 20.59 | 19.93 | 18.60 | 19.19 | +3.2% |
| Total consumption | 72.1 | | 78.0 | 77.8 | 75.0 | 73.0 | -2.7% |

*Strategic petroleum reserve storage began in October, 1977.

Source: Monthly Energy Review DOE/EIA-0035 (82/05) Revised data as of May 1982. Some figures differ from those on earlier flow charts.

slightly (+0.6 percent), but foreign imports were down 14 percent from 1980. (Figure 3.) The drop in oil imports and oil consumption in general accounts for the drop in total energy consumption from 75 quads ($10^{15}$ Btu) in 1980 to 73 quads in 1981. The principal petroleum product reflecting the decrease in oil consumption was residual oil (Table 2). Some fraction of its use was curtailed by a sluggish economy and another by fuel-switching by cost conscious utilites. By the end of 1981 the price of delivered residual oil was three times the price of coal on a comparable Btu basis and one and one-half times the price of natural gas. The American Petroleum Institute attributes 14% of the 18% drop in residual oil use to switching to coal for electric power generation.[5]

TABLE 2. Petroleum products.*

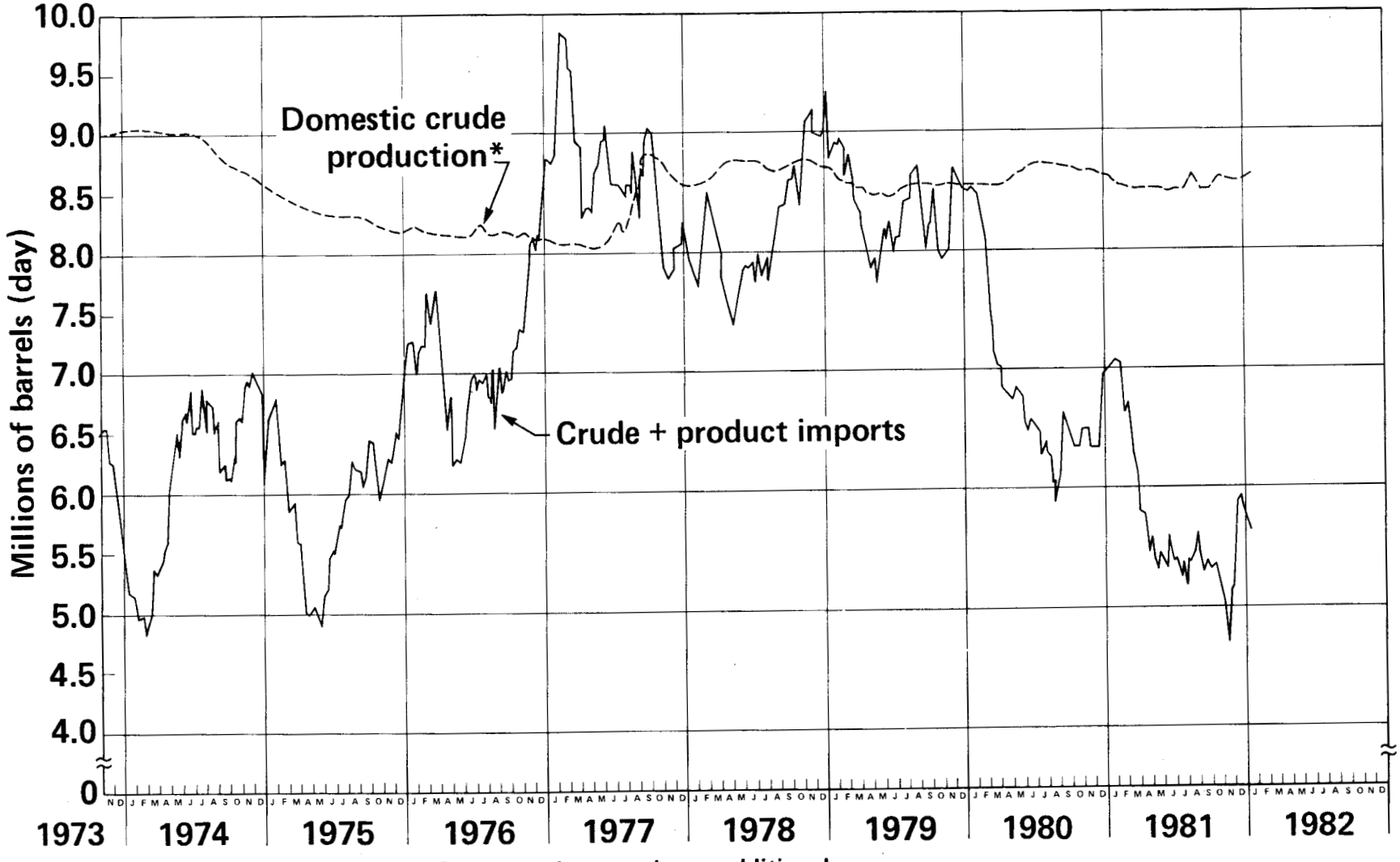
| | $10^3$ barrel/day (average) | | | | | |
|---|---|---|---|---|---|---|
| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
| Motor gasoline | 6,978 | 7,177 | 7,412 | 7,034 | 6,579 | 6,586 |
| Jet fuel | 987 | 1,039 | 1,057 | 1,076 | 1,069 | 1,011 |
| Distillate fuel oil | 3,133 | 3,352 | 3,432 | 3,311 | 2,866 | 2,830 |
| Residual fuel oil | 2,801 | 3,071 | 3,023 | 2,826 | 2,508 | 2,062 |

*Refined petroleum product supplied: sum of production, imports, net withdrawals from primary stocks minus exports.

Source: Monthly Energy Review, DOE/EIA-0035 (82/05); 1981 Annual Report to Congress: DOE/EIA-0173(81)/2, Vol. 2 of 3 Energy Statistics, May 1982.

## PETROLEUM IMPORTS AND DOMESTIC PRODUCTION

Moving four week average




*Note: NGL currently comprise an additional ~1.5 million barrels/day domestic oil production

Figure 3

Despite increased average passenger car efficiencies, the consumption of gasoline remained at 1980 levels. Overall transportation use increased slightly (3.2%) after falling in 1980. Conversion to diesel fuels continued in 1981, but it has no clear expression in the data of Table 2.

The American Gas Association reported that conversion to natural gas by residential and commercial users reached a record high. Nonetheless North America was the only major industrialized nation in the world that did not record a net increase in natural gas usage.[6]

Nineteen eighty-one saw the end of federal price controls on domestic crude oil production. The phased de-control began in April 1979 and ended in January 1981, at which time only 15% of oil remained under control. The effect on 1981 domestic production was small as far as can be determined.

During 1981 filling of the Strategic Petroleum Reserve (SPR) was accelerated. This was a felicitous time since there was a surplus of oil on international markets, and prices were "soft". For the first time the government purchased substantial amounts of domestic oil for SPR. Nevertheless imports constituted 76% of the total purchases. The volume in SPR rose from 108 million barrels at the end of 1980 to 230 million barrels at the end of 1981. Surplus oil on international markets in 1981 was due to declining world-wide consumption, large stock-drawdowns within individual countries and reduced, but more than adequate, oil production.

The source of U.S. oil imports continued to change in 1981 (Table 3). However OPEC continued to provide the bulk of U.S. imports as it had prior to the 1973 embargo, 66.3% in 1981. While Iranian and Iraqi production declined (Figure 4) and exports to the U.S. were discontinued in 1981, Saudi Arabian

TABLE 3. Selected developed countries: crude oil imports, by source.

| | Thousand b/d | | | | | | Percent of total | |
|---|---|---|---|---|---|---|---|---|
| | Sept. 1973 (Pre crisis level) | 1977 | 1978 | 1979 | 1980 | 1981 | Sept. 1973 | 1981 (ave.) |
| United States | | | | | | | | |
| Algeria | 124 | 544 | 634 | 608 | 452 | 253 | 3.6 | 5.7 |
| Egypt | -- | 36 | 20 | 55 | 31 | 23 | -- | 0.7 |
| Iraq | 17 | 74 | 62 | 88 | 88 | -- | 0.5 | -- |
| Kuwait | 44 | 42 | 5 | 5 | 20 | -- | 1.3 | -- |
| Libya | 153 | 704 | 638 | 642 | 546 | 318 | 4.4 | 7.2 |
| Qatar | 41 | 67 | 64 | 31 | 22 | 7 | 1.2 | 0.2 |
| Saudi Arabia | 599 | 1373 | 1142 | 1347 | 1247 | 1111 | 17.3 | 25.2 |
| United Arab Emirates | 88 | 333 | 385 | 281 | 179 | 78 | 2.5 | 1.8 |
| Other | -- | -- | 7 | 11 | 2 | 6 | -- | 0.1 |
| Ecuador | 33 | 55 | 38 | 30 | 16 | 36 | 1.0 | 0.8 |
| Gabon | -- | 35 | 38 | 42 | 25 | 35 | -- | 0.8 |
| Indonesia | 249 | 507 | 533 | 380 | 307 | 319 | 7.2 | 7.2 |
| Iran | 205 | 530 | 554 | 297 | 7 | -- | 5.9 | -- |
| Nigeria | 409 | 1130 | 910 | 1069 | 831 | 612 | 11.8 | 13.9 |
| Venezuela | 405 | 250 | 181 | 293 | 154 | 150 | 11.7 | 3.4 |
| Total OPEC | 2367 | 5644 | 5184 | 5113 | 3894 | 2919 | 68.2 | 66.3 |
| Canada | 998 | 279 | 248 | 271 | 199 | 164 | 28.8 | 3.7 |
| Mexico | 8 | 177 | 316 | 435 | 504 | 471 | 0.2 | 10.7 |
| U.K. | -- | 97 | 169 | 197 | 174 | 368 | -- | 8.4 |
| Norway | -- | 48 | 104 | 75 | 141 | 114 | -- | 2.6 |
| Other | 98 | 332 | 308 | 362 | 275 | 331 | 2.8 | 7.5 |
| Total | 3471 | 6615 | 6356 | 6519 | 5220 | 4406 | 100. | 100. |

Source: International Energy Statistical Review, 25 May 1982, GI IESR 82-005, CIA, Directorate of Intelligence, p. 5.

# OPEC CRUDE OIL PRODUCTION*

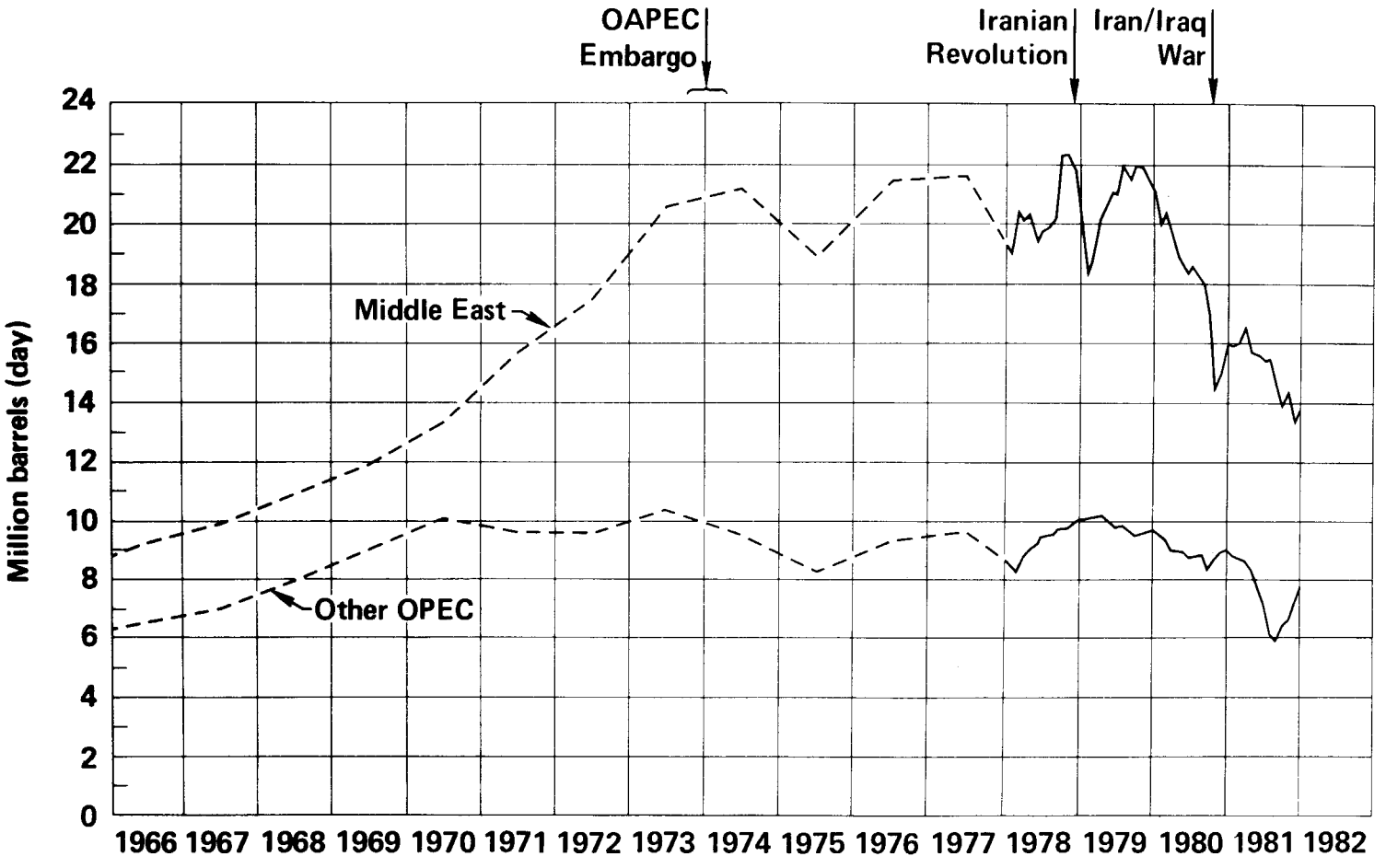



Figure 4

imports rose to more than cover the loss. Nonetheless, new non-OPEC suppliers such as Mexico were becoming more important to the U.S. In 1981 Mexico supplied 471,000 barrels per day or 11% of our imports as compared to 8,000 barrels per day in September, 1973 (Table 3).

After a strong resurgence of coal use in the U.S. starting in 1979, coal consumption rose only slightly in 1981. The price differential between oil and coal, although substantial, grew smaller and the fuel-switching that has been going on for the past few years was slowed. The recession similarly affected plans to retro-fit equipment to burn coal by the utilities. Exports increased substantially over 1979 levels (2.9 quads as compared to 1.7 quads), however large stockpiles in Europe and strong competition from Australia and South Africa for markets are believed to have dampened U.S. exports. A coal miners' strike in the second quarter resulted in drawdown in U.S. stocks as shown in the flow chart of Fig. 1.

Total transmitted electrical energy in 1981 was essentially the same as in 1980. Fuels burned for power generation continued to be dominated by coal. Nuclear energy provided approximately 12% of the total domestic electricity generation, but still less than in 1978 (Table 4). Four reactors were licensed and two were dropped from the count during the year. Capacity at year end was 56 $GW_e$. The count does not include the Humboldt Bay, CA, Dresden-1 or Three-Mile Island -2 reactors; it includes the reactor at Fort St. Vrain and the fast-breeder planned at Clinch River, Tennessee. Nineteen eighty-one projections of future U.S. nuclear capacity remain conservative (Fig. 5) as compared to past estimates. The projections in Fig. 5 are by the Department of Energy.

TABLE 4. Nuclear development status of nuclear reactor units.*

| | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|
| Licensed reactors | 62 | 67 | 71 | 71 | 72 | 74 |
| Construction permits granted | 72 | 80 | 90 | 91 | 82 | 75 |
| Construction permits pending | 66 | 52 | 32 | 21 | 12 | 11 |
| Reactor units on order | 16 | 13 | 9 | 3 | 3 | 3 |
| Total reactor units | 235 | 221 | 206 | 186 | 169 | 163 |
| Total design capacity (million net† kW) | 236 | 220 | 204 | 180 | 163 | 157 |
| Nuclear portion of domestic electricity generation (%) | 9.4 | 11.8 | 12.5 | 11.4 | 11.0 | 11.9 |

*As of December 31 of each year

†Minus nominal station service load (∿5%)

Source: Monthly Energy Review, DOE/EIA-0035 (82/05)

## ROLES OF THE RECESSION AND CONSERVATION IN DECLINE OF ENERGY USE

Within the U.S. declining energy use (and associated oil consumption) has been attributed to the combined effects of an economic recession, price-driven conservation and increased efficiencies in end-use. The shares attributable to these factors are elusive. DOE's Office of Policy, Planning and Analysis contends that almost 40% of the decline is related to slow economic growth,

# PAST PROJECTIONS OF U.S. NUCLEAR CAPACITY

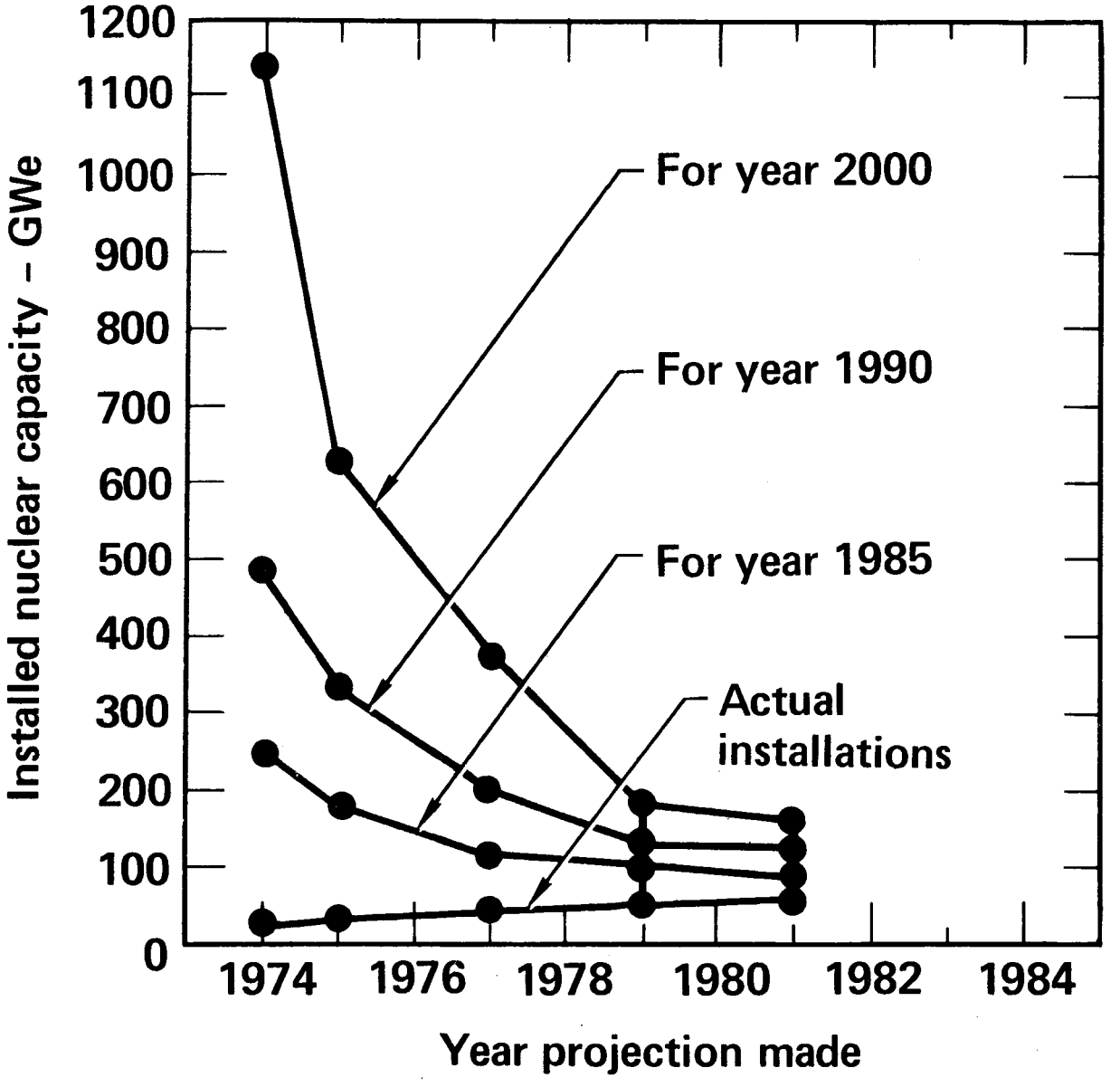



Figure 5

30% to high prices and the remainder to increased efficiencies (11%) and other factors such as the general trend from heavy to light industry.[7] Others, such as Hans Landsberg of Resources for the Future, relate 50% of the decline to the recession, and 50% to other factors.[8] For a given dollar of U.S. GNP oil consumption has declined faster than all energy consumption - again indicating that issues other than the recession are responsible for the drop in overall energy use (Table 5).

TABLE 5. Total energy and petroleum consumption per constant dollar of GNP.[9] (Quadrillion Btu per trillion 1972 dollars.)

| | 1979 | 1980 | 1981 |
|---|---|---|---|
| Total energy consumption | 53.2 | 51.3 | 48.9 |
| Petroleum consumption | 25.0 | 23.1 | 21.2 |

A similar situation has been documented by the International Energy Agency for its 21-member countries.[10] The so-called oil/GDP* has decreased by an average 2.8% per year. For some countries the decrease over the period 1973-1980 has been spectacular, e.g., Japan (27.3%), U.K. (31.8%), West Germany (24.8%) and Italy (21.2%). For the U.S. the decrease was 13.7%. Most of the change occurred after 1979.

*Gross domestic product

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## APPENDIX: CONVERSION FACTORS

The energy content of fuels varies. Some approximate, rounded conversion factors, useful for estimation, are given below.

| Fuel | Energy Content (Btu) |
|---|---|
| Short ton of coal | 22,500,000 |
| Barrel (42 gallons) of crude oil | 5,800,000 |
| Cubic foot of natural gas | 1,000 |
| Kilowatt hour of electricity | 3,400 |
| Fossil fuel to produce one kilowatt hour of electricity | 10,400 |

More detailed conversion factors are given in the Department of Energy's Monthly Energy Review.

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